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FOR
ENERGY SYSTEMS
OPTIMIZATION PROGRAM 2 (ESOP2)
VOLUME I - ENGINEERING MANUAL
CPD 714

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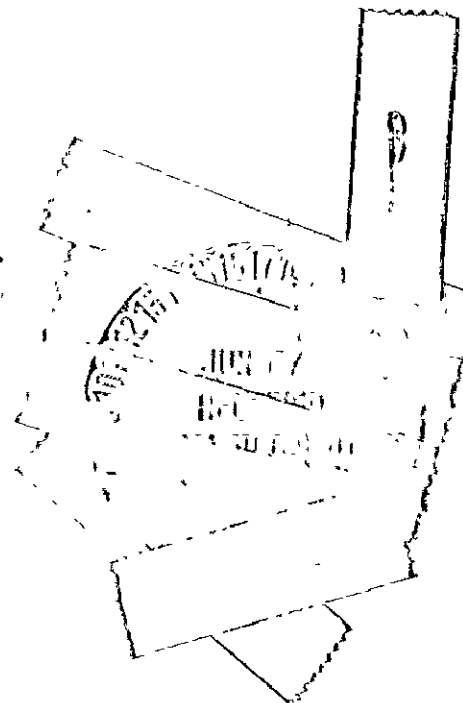


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FOR
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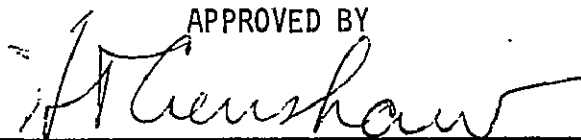


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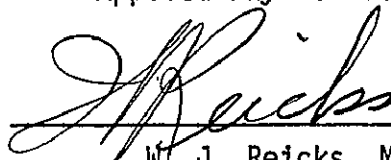


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FOREWORD

This document represents the results of a developmental study by Lockheed Electronics Co. - Systems and Services Division (SSD) to produce a computer program, which will provide energy analyses of energy conversion systems, such as the Modular Integrated Utility Systems (MIUS). The program title is Energy Systems Optimization Program 2 (ESOP2).

A MIUS is designed to provide communities of limited size with the required utility services of electric power generation, heating and cooling sources, potable water supply, waste water treatment, and solid waste disposal.

This study was funded by both the Department of Housing and Urban Development (HUD) and the Systems Evaluation Office (SEO) of the NASA/Johnson Space Center and was under the overall direction of HUD. The technical monitor for the study was Mr. Richard C. Wadle of SEO. The authors wish to thank Mr. Wadle for his support, critique, and timely suggestions throughout the duration of the study. Credit is also acknowledged to other members of SEO, HUD, and the National Bureau of Standards, who participated in the development, application, and/or evaluation of the program which developed from this study.

The authors also wish to acknowledge the support of SSD personnel who contributed to the development and application of this program. These include: Dr. J. L. Allison, who was instrumental in the incorporation of the optimization feature into the program, Ms. E. C. Osborne, who developed the waste water treatment subroutine, Mr. E. S. Riley, who incorporated the economic data base and financial subroutines into the program, and Mr. W. C. Rochelle and Mr. D. K. Liu, who were responsible for a number of analyses, using various applications of the program. Finally, the authors wish to acknowledge the technical support and direction of Mr. R. D. Stallings, who was the project leader for two years and personally incorporated a number of important features into the program.

SUMMARY

This document is a complete revision of previous documents describing the Energy Systems Optimization Program, which is used to provide analyses of Modular Integrated Utility Systems (MIUS). The program has now been given the acronym ESOP2 rather than the previously designated ESOP. Principle changes in the program which are described in this document include:

- Modifications to the input format to allow modular inputs in specified blocks of data.
- An optimization feature which enables the program to search automatically for the minimum value of one parameter while varying the value of other parameters.
- New program option flags for prime mover analyses.
- Inclusion of solar energy for space heating and domestic hot water.

The document is presented in four volumes: (1) Volume I - Engineering Manual, (2) Volume II - User's Manual, (3) Volume III - ESOP2 Program Listing and (4) Volume IV - Economic and Financial Analysis Program and Users Guide. The present volume (Vol. I) contains the method of analysis, description of program subroutines and a program flow chart.

1. INTRODUCTION

The Energy Systems Optimization Program was written by Lockheed Electronics Company/Systems and Services Division (SSD) under the direction of the Systems Evaluation Office (SEO) of NASA/Johnson Space Center (JSC). The program was written to analyze the operating performance and costs of energy conversion systems, including the Modular Integrated Utility Systems (MIUS) and to compare the MIUS performance and costs with those of a conventional utility system.

The Department of Housing and Urban Development (HUD) has had the overall direction of the MIUS Program and has sponsored, along with the SEO, the development and application of the Energy Systems Optimization Program 2. The general objectives and applications of the MIUS Program may be found in Ref. 3. Basically a MIUS system is designed to help alleviate the current energy shortage by integrating various utility services together, generating on-site electricity, and using prime mover recovered heat for absorption air conditioning, space heating, domestic hot water, waste water treatment, or transferring this heat to thermal storage for later use.

The development of the Energy Systems Optimization Program as applied to MIUS systems began at SSD in the Fall of 1972 with the development of two sub-programs; solid waste disposal calculations and heating and air-conditioning demand calculation. The first complete user's guide was published in May 1973 which described the analysis of the following systems integrated together: (1) solid waste disposal, (2) heating and cooling loads, (3) energy requirements, (4) electric power generation, and (5) conventional utility system. Further updates to the program were developed over the next eighteen months and incorporated such features as: multiple executions for a number of buildings of different types, all-electric options, potable water requirements, waste water treatment, modified heating/cooling load calculations, thermal storage, improved low grade heat utilization, economic data base, financial analysis and the solar heating of buildings.

This document describes several new and important changes to the Energy Systems Optimization Program, which will hereafter be designated ESOP2. These changes include the following:

- Modifications to the input format to allow modular inputs in specified blocks pertaining to: (1) program option flags, (2) weather data, (3) building data, (4) load profiles, (5) equipment data arranged into various categories (e.g., diesel/gas engines, steam power plants, solid waste disposal, solar energy, secondary conversion, thermal storage, cooling tower, and waste water treatment), (6) fuel and electricity data, and (7) optimization data.
- An optimization feature which allows the program to search automatically for a minimum value of a parameter as a function of other system parameters.
- New program option flags to limit the maximum number of prime movers desired, the number of hours at which a prime mover may operate at over 100% of its rated load and the maximum overload allowed on the prime mover. This feature is also incorporated with the optimization analysis.
- The capability to make an energy analysis for 8,760 hours or 12 days, in addition to previous options.

The present document is presented in four volumes as described below:

- Volume I - Engineering Manual: Description of methods and types of analysis along with discussion of each subroutine and applications of the program. A flow chart of the program is also included.
- Volume II - User's Manual: Description of program input data and output data and a sample computer listing of the input and output for several cases.
- Volume III - Program Listing: Complete computer listing of main program plus all subroutines.
- Volume IV - Economic and Financial Analysis: Descriptive users guide of the economic and financial analysis program including examples.

2. METHOD OF ANALYSIS

2.1 ENERGY SYSTEMS CONCEPT

The method of analysis used with the ESOP2 Program is based on the energy conversion system configuration shown in Figure 1. In this figure there are five basic subdivisions: (1) input, (2) primary sources or "prime movers", (3) heat storage/conversion, (4) uses, and (5) waste. Basically, energy is put into the system, a portion of the energy is converted to meet system loads and a certain amount of heat is rejected from the system. Any of the blocks on this figure may be used in a MIUS system; however, only the shaded blocks are considered for a conventional system.

The user of ESOP2 may use the components of Figure 1 to design his own energy system or to evaluate a system, which may be a modified total energy or conventional system. By definition, a "conventional system", as used in this document, is defined as a system which:

- Obtains the electricity to meet the domestic, auxiliary, and compression A/C electric demands from a fossil-fired power plant whose plant efficiency is input to the program (e.g., 30%).
- Uses an all-compression A/C system (electrically driven) with an input COP (e.g., 4.0) to meet the space cooling demand.
- Uses a fossil-fired boiler to meet the domestic hot water and space heating demands.
- Has no heat recovery, thermal storage, waste water treatment, solid waste disposal, absorption chillers, solar collectors or on-site electric generation.

A "Total Energy System" (TES), as used in this document, is defined as a system, which has the classical elements, plus "MIUS" elements. The system may:

Energy Conversion System Configuration

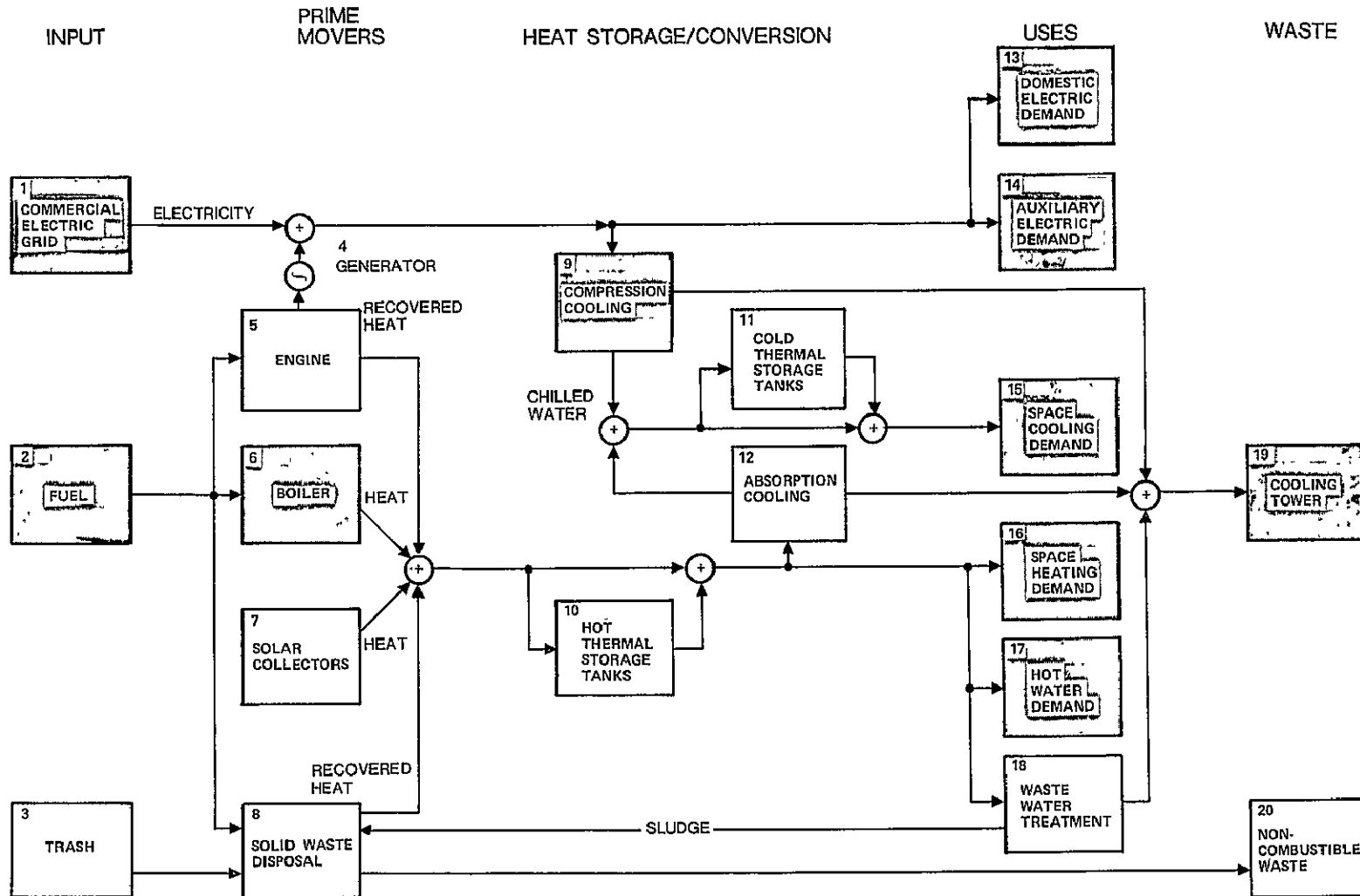


FIGURE 1
2-2

- Use an engine/generator to furnish or supplement the grid of the electricity for meeting all the electric demands.
- Use recovered heat from the engine/generator to meet the domestic hot water, space heating and space cooling (absorption chiller) demands.
- Use a boiler to meet any remaining heating demands not met from recovered heat.
- Use a compression chiller to meet any remaining space cooling demands not met by recovered heat.
- Have a solid waste disposal system with recovered heat available for meeting heating and cooling demands.
- May have a waste water treatment facility where sludge may be used for input to the solid waste disposal process.
- May have a hot and/or cold thermal storage tank which may be used as a secondary source of energy to the system.
- May have an array of solar collectors, the heat from which would be used for meeting space heating demands and domestic hot water demands.

As an aid in describing the method of analysis used with ESOP2, a brief discussion will be given for each of the blocks in Figure 1:

- Block 1 is the commercial electric grid. All or part of the power furnished to the system may come from this source. The local electric rates may be input to the analysis and the cost of the electricity used is generated in the analysis.
- Block 2 is the fuel used by the equipment making up the system. It may be gasoline, natural gas, coal, fuel oil, or a liquid petroleum gas (LPG).
- Block 3 is the residential trash that is generated in the complex being studied. The trash is fed into the incinerator as fuel.

- Block 4 is the generator which is driven by an engine. The characteristics of the generator are input parameters for the analysis. The generator furnishes electricity to the system to supplement or replace the grid.
- Block 5 is an engine, which drives the generator and has fuel as an input. Its output includes recovered heat which will be used elsewhere in the system. The engine characteristics are input parameters to the analysis. The fuel used may be diesel, gasoline, natural gas or an LPG.
- Block 6 is the conventional boiler to produce hot water or steam. Boiler parameters such as pressure, temperature and fuel are input to the analysis and the heat generated is output to the heating requirements.
- Block 7 represents the solar input to the analysis. Calculations are made to determine the solar collector energy based on the collector characteristics, orientation, and weather data for the area in which the building is located. The thermal energy developed by the solar collectors may be used in the space heating system and domestic hot water system. The prominence of solar collectors is expected to be greatly increased in view of the present energy situation.
- Block 8 is the solid waste disposal system, which accepts residential type solid waste (trash), fuel, and sludge as inputs. These items are burned and the outputs are heat, which can be used in some other processes in the TES, and the noncombustible waste.
- Block 9 is the compression air-conditioning compressors. The compressors are driven by electric motors and their output is chilled water and waste heat.
- Block 10 is the hot thermal storage tanks that are used in TES's. Heat that is not needed for immediate use is stored in the tank for use later on in the day. This type of storage can be used to balance the 24 hour load on a building by storing hot water energy during low load periods and utilizing it during high load hours.

- Block 11 is the cold thermal storage tanks that are used in TES's. The cold water is stored for future use in the space cooling demand. The same load balancing effects can be used here as was suggested in the hot storage tanks.
- Block 12 is the absorption air conditioning chiller which receives heat from the incinerator, engine/generator and/or boiler. The output is chilled water for space cooling and thermal storage and waste heat.
- Block 13 is the domestic electric demand. This includes all electric demands other than the heating and cooling loads of the building. It would include all items which introduce heat into the conditioned space such as lighting. These load profiles are input to the analysis, based on the type of building being considered in the analysis.
- Block 14 represents the auxiliary electrical demand. All electric demands not previously accounted for are included in the auxiliary demand.
- Blocks 15 and 16 are related in that weather data and building characteristics are common. The building data includes type of construction, number of floors, wall, roof and glass area, orientation, and general building parameters. The weather data is hourly data, based on local climate. The respective heating and cooling loads are calculated and used in the analysis.
- Block 17 considers the hot and cold potable water requirements based on the type of building and its occupancy.
- Block 18 is the waste water treatment, which utilizes some of the recovered heat to produce sludge and treated water which are used in other parts of the system.
- Block 19 is the cooling tower which dissipates the waste heat which cannot be used in any processes.
- Block 20 is the non-combustible waste from the solid waste disposal unit. This waste must be removed from the system, since it cannot be used for any other process.

2.2 MODELING

Both loads and equipment are modeled in an ESOP2 analysis. Section 2.2.1 presents a description of the loads modeling, while Section 2.2.2 gives a description of the equipment modeling.

2.2.1 LOADS

This section describes the various types of loads which are required in an ESOP2 analysis. Five general types of loads are modeled for each system: space heating and cooling, potable water, waste water, solid waste, and electricity. If the loads are not modeled, profiles may be input.

The space heating and cooling loads are calculated, based on three types of data: weather, building, and input profiles. The weather data may be input by either standard weather tapes or computer cards giving indoor and outdoor temperatures and enthalpies, cloud cover and other information. The building data includes such things as latitude, longitude, time zone, azimuth angle, conductivity factors and surface areas of the walls, windows, and roof. Both single building and multiple buildings of various types (apartments, hotels, offices, residences, townhouses, schools and hospitals) may be modeled. The input 24-hour profiles include occupancy, occupant metabolic rate and ventilation rates.

The potable water requirements may either be computed by the model if the building is a residential-type building or may be input in a profile if the building is commercial. The model will compute the hot and cold water usage for the kitchen, laundry, and bath for apartments, townhouse, and single-family residences.

Waste water treatment may be utilized in the analysis. The change in quality of effluent and sludge are calculated as a function of the treatment processes. Presently, eleven processes are modeled. Both generic treatment processes and specific manufacturers equipment may be used in the model.

The solid waste disposal requirements are computed for three specific processes: incineration, pyrolysis, and combination processes. Operating parameters are input and daily total energy requirements are calculated for these solid waste processes.

The electric requirements are modeled by inputting hourly profiles of the domestic electric load and the auxiliary electric load. The domestic electric load includes the indoor lighting and equipment electric loads, which introduce heat into the conditioned spaces. The auxiliary electric load includes the outdoor lighting and equipment electric loads, which do not introduce heat into the conditioned spaces.

2.2.2 EQUIPMENT

This section describes some of the equipment characteristics modeled in an ESOP2 analysis. Types of prime movers which have been modeled include dual-fuel engines, gas turbines, and steam turbines. Size ranges investigated include 315-7624 KW sizes for engines and 400-7500 KW for turbines. Boilers have been modeled, using gas, oil, and coal as fuels. Boiler size requirements have ranged from hundreds to several hundred thousand lbs. of steam per hour. Other types of equipment modeled in analyses have included incinerators and pyrolysis units, absorption and compression chillers, thermal storage tanks, heat exchangers, cooling towers, and solar collectors.

Profiles of heat recovery and fuel consumption for prime movers are input to the analysis as a function of generator load from zero load up to 120% load. Based on the total electric demand at a particular point in time, the computer program interpolates on these profiles to obtain the correct value to use in the analysis.

Among the operating parameters used for the equipment are the capacities of the units, efficiencies and coefficients of performance, and the various constraints on the system. These constraints include maximum and minimum operating

temperatures, pressures, flow rates, loads, number of units, and number of hours for overload (over 100%).

The number of each type of equipment depends on the maximum assumed operating point (e.g., 90%) of the equipment. When a new unit comes on line the loads may be split evenly among all equipment (as in the case of prime movers), or a new unit may be allowed to go from its minimum operating point to its maximum where all other equipment of the same type operate at their maximum operating point (in the case of boilers).

2.3 ANALYSIS TECHNIQUES

Three general techniques of analysis are performed in the ESOP2 Program. These techniques include: (1) energy analysis, (2) economic analysis, and (3) optimization. Each of these techniques are discussed in detail in the next three sections.

2.3.1 ENERGY ANALYSIS

The energy analysis performed in the ESOP2 program is divided into four categories: (1) space conditioning (HVAC), (2) electric power, (3) total energy or MIUS Systems, and (4) conventional system. Each of these categories are described in the next four sections.

2.3.1.1 Space Conditioning

The space conditioning loads on a particular building are computed as the sum of five heat sources: (1) radiation through the windows, (2) conduction through the roof, walls, and windows, (3) ventilation air rate, (4) occupant metabolic rate, and (5) domestic electric load dissipated in the building. The detailed analysis of these hourly loads (including equations) may be found in the description of Subroutine HEAIR.

2.3.1.2 Electric Power

The total electric power requirements are computed as the sum of (1) domestic electric load, (2) auxiliary electric load, (3) compression A/C electric load. The compression A/C electric load is calculated by an iteration method in the program, based on the difference between the total cooling load minus the cooling supplied by the absorption chiller. The description of this iteration method is found in the discussion of Subroutine AIRHT.

2.3.1.3 Total Energy or MIUS System

In a total energy or MIUS system, devices are used for collecting and using heat energy that is normally lost or wasted in a conversion process. The energy analysis performed in ESOP2 for such a system is designed to make as much use as possible of this recovered energy in meeting load demands. In addition the analysis permits the use of supplementary solar energy if the system under study is so equipped. Generally, all energy collected from special devices is used to meet hot water, heating, absorption air-conditioning and waste treatment demands. Under certain program options any waste energy remaining after demands are met may be placed in thermal storage for use at a later time. Otherwise it is lost. In all cases an hourly summary of energy input to the system as fuel, energy collected by various devices, energy used in meeting load demands and energy lost is computed.

Recovered heat is classified as high grade or low grade depending on whether the temperature at which it is recovered is high enough to drive our absorption air-conditioner. This is not a clear cut criterion and it is subject to change with the state of the art in absorption chillers. However, in ESOP2 typical sources of high grade heat are the incineration process and the exhaust jacket of internal combustion engines. Typical sources of low grade heat are solar collectors, engine oil after cooler and engine water jackets. Actual use of recovered heat depends on whether the prime mover is an internal combustion engine or a steam plant.

2.3.1.3.1 Internal Combustion Engine System

The "internal combustion engine: MIUS may, through the use of input options, be composed of all elements depicted in Figure 1. A minimum configuration will include the prime mover/generator for meeting electric loads, one boiler to meet heating and hot water and absorption air-conditioning demands, and one of four possible air-conditioning systems. These are (1) all compressions, (2) all absorption, (3) fixed split percentage between absorption

and compression, and (4) floating split percentage between absorption and compression. If the floating split air-conditioning system is chosen the energy system may include thermal storage.

For each hour the amount of heat recovered from the engine is determined. The waste disposal operating schedule is used to determine recovered heat available from that source. Finally, energy available from solar collectors is computed. Recovered heat is then allocated to meet the environmental control system demands and hot water demands. If more heat is available than is needed the remainder is either lost or is placed in thermal storage. If recovered heat is not sufficient to meet system demands supplementary heat may be taken from thermal storage if it is available. Additional heating requirements are satisfied by firing the boiler. Additional air-conditioning requirements are satisfied by either compression air-conditioning or by firing the boiler depending on the air-conditioning option chosen.. If additional compression air-conditioning is used, the additional usage of the engine leads to more recovered heat. This heat is considered in the hourly computation of the energy balance.

2.3.1.3.2 Steam Power Plant

Program design limits the choice of a steam power plant to one of four specific systems. These systems are shown in figures 3-6 of section 3.7 which describes the operation of subroutine STEAM. These four options together with a choice of three different solid waste disposal systems lead to 12 specific system configurations as shown in Table I. The user selects a specific system by specifying a mode number at program setup for both the steam power plant (options 1-4) and for solid waste disposal system. The modes for solid waste disposal are: (1) Incinerator, (2) Pyrolysis and (3) combination incinerator/pyrolysis. Methods of heat recovery and uses of recovered heat are depicted in figures 1-4.

TABLE I
STEAM POWER PLANT CONFIGURATIONS

| <u>MODE</u> | <u>TYPE OF SYSTEM</u> | | |
|-------------|-----------------------|---|----------------------------|
| 1 | INCINERATOR | - | OPERATING SYSTEM NO. ONE |
| 2 | PYROLYSIS | - | OPERATING SYSTEM NO. ONE |
| 3 | INCIN/PYROL | - | OPERATING SYSTEM NO. ONE |
| 4 | INCINERATOR | - | OPERATING SYSTEM NO. TWO |
| 5 | PYROLYSIS | - | OPERATING SYSTEM NO. TWO |
| 6 | INCIN/PYROL | - | OPERATING SYSTEM NO. TWO |
| 7 | INCINERATOR | - | OPERATING SYSTEM NO. THREE |
| 8 | PYROLYSIS | - | OPERATING SYSTEM NO. THREE |
| 9 | INCIN/PYROL | - | OPERATING SYSTEM NO. THREE |
| 10 | INCINERATOR | - | OPERATING SYSTEM NO. FOUR |
| 11 | PYROLYSIS | - | OPERATING SYSTEM NO. FOUR |
| 12 | INCIN/PYROL | - | OPERATING SYSTEM NO. FOUR |

2.3.1.4 Conventional System

For a conventional system the energy and fuel requirements are computed based on an assumed efficiency for the power plant (e.g., 30%), an all-compression A/C system with assumed COP (e.g., 4.0) to meet the space cooling demands and a boiler to meet the hot water and space heating demands. There is no heat recovery in the conventional analysis. Further discussion of the conventional system may be found in the description of Subroutine CONVEN.

2.3.2 ECONOMIC ANALYSIS

The economic analysis is performed separately, using the energy analysis results as input.

The discussion of the economic analyses will be divided into two general categories: costing analysis and financial analysis. A simplified flow chart is presented in Figure 2, which shows the flow from the energy analysis (both design and seasonal loads) to the costing analysis and the financial analysis. A detailed discussion is given in volume 4.

2.3.2.1 Costing Analysis

An economic data base comprising about 130 tables of various capital costs, O & M costs, energy costs, debt service and administrative costs is incorporated into the costing subroutine, ECOBAS. The costing of complex energy systems is difficult because of the factors which must be considered, such as:

- The large number of equipment components which go into making an energy system.
- The regional variation in cost which may be significant in equipment, cost of installation or labor rates.

ECONOMIC/FINANCIAL ANALYSIS

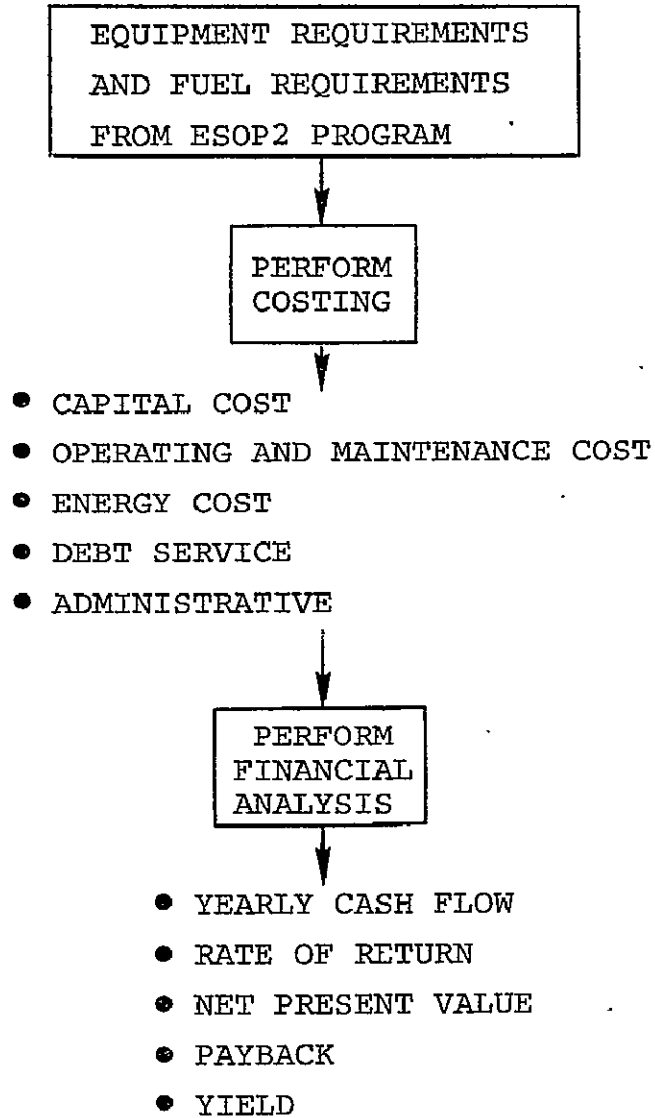


FIGURE 2 INFORMATION FLOW THROUGH ECONOMIC/FINANCIAL ANALYSIS

- The significant rate of inflation in recent years makes costs estimates obsolete in a short time. (Data currently in ECOBAS is obsolete).

A computerized information system was developed to aid in the costing of the systems. Highlights of this system include:

- (1) Developing a list of the major system components.
- (2) Developing tables of cost for labor and all major components and transferring this data to a data base. This data base also includes city cost indices for both equipment and labor for 12 U. S. cities, and electricity, water and sewer, natural gas, oil, and coal costs for each state.

The "equipment list", which lists the cost components of each of the major systems which influence the economics of a TES, is presented in Volume IV describing Subroutine ECOBAS.

2.3.2.2 Financial Analysis

There are a number of financial factors which must be included in selecting an energy system. These include the following:

- yearly cash flow
- return on investment
- net present value
- payback
- yield

Other factors to be considered are depreciation method, tax rates, system life and system value. The depreciation may be calculated using straight line, sum of years digit, or declining balance method. Further details on the financial analysis may be found in Volume IV in the discussion of the Subroutine FINANS.

The combination of the computerized costing and the financial analysis routines provides a very useful tool in making investment decisions. It allows simulation of various system life cycles; e.g., the effect of inflation on the economic feasibility of the system can be studied by applying cost escalation factors to the yearly costs.

2.3.3 OPTIMIZATION

The optimization capability is used to automatically drive some desired variable to a minimum while varying specified equipment parameters to their optimum value. This capability is an optional feature of the program. A single variable object function must be written to specify the criteria for optimization. The optimizer is the driving function for ESOP2 when it is utilized in the program. The subroutine SEARCH defines the method used. There are 9 variables shown in Table II which may presently be optimized in the program. The object functions to be minimized, are limited to (1) total fuel cost, (2) total BTU's required for heating and cooling, and (3) total purchased BTU's. The User's Manual (Vol. II) instructs the user on how to choose a particular function.

TABLE II OPTIMIZATION PARAMETERS

| | SIZE | MAX LOAD | TEMP | THICKNESS | ORIENTATION |
|----------------------|------|-------------|------|-----------|-------------|
| PRIME MOVER A | X | | | | |
| PRIME MOVER B | X | | | | |
| PRIME MOVER A | | X | | | |
| PRIME MOVER B | | X | | | |
| SOLAR COLLECTORS | | | | | X |
| WALL INSULATION | | | | X | |
| BUILDING | | | | | X |
| COLD THERMAL STORAGE | X | | | | |
| HOT THERMAL STORAGE | X | | | | |

Note: Any combination of parameters may be used in a single run with the exception that size and max load for a single prime mover may not be used together.

3. PROGRAM SUBROUTINES

This section presents a discussion of each of the ESOP2 subroutines. A program flow chart showing how most of these subroutines are integrated into the program is given in Section 4.0.

3.1 DRIVER MAIN

Subroutine MAIN is the main driver of ESOP2. Subroutine MAIN calls subroutine LEAP and/or SEARCH depending on the optimization flag setting.

3.2 SUBROUTINE LEAP

In subroutine LEAP, all of the input data is read in by formatted read statements. This data is arranged in specified blocks pertaining to the following categories:

- Program option flags
- Weather data
- Building data
- Load profiles
- Equipment data
- Waste water treatment data
- Waste disposal data
- Fuel and electricity data

The equipment data is further arranged into the following categories:

- Diesel/gas engines
- Steam power plants
- Solid waste disposal
- Solar energy
- Secondary conversion systems
- Thermal storage systems
- Cooling tower
- Waste water treatment

Subroutine LEAP also prints out an echo of all of the input in three namelists : OUT, OUT1, and OUT2.

3.3 SUBROUTINE SWDP

Subroutine SWDP calculates operating parameters and daily total energy input required for three types of solid waste disposal systems: incineration, pyrolysis, and combination incineration/pyrolysis. Process by-products and recoverable waste energy are also calculated. The processes are discussed below.

3.3.1 INCINERATION PROCESS

The total daily waste (lbs) generated is a function of input values of the waste generation rate per person (lbs/day), the total number of occupants and the sludge input from the waste water. The total moisture (lbs) and non-organics (lbs) are calculated from input percent (of total waste) values of moisture and non-organics. The total weight (lbs) of organic trash material (combustibles) is then calculated

$$\text{Organics (lbs)} = \text{Total Trash (lbs)} - (\text{moisture} + \text{Non-Organics}) \text{ (lbs)}$$

The daily fuel energy requirement (BTU's) for the incineration process is composed of start-up fuel energy and supplementary fuel energy (required to sustain combustion). The total fuel energy requirement is calculated by

$$\text{Total Energy Required (BTU's)} = \text{Start-up (BTU's)} + \text{Supp. Energy Rate (BTU's/HR)} \times \text{Operating Time (HRS)}$$

where start-up and supplementary energy requirements are input values.

The heat generated by combustion of the trash is a function of the input trash heating value (BTU/lb). The total amount of heat (BTU's) generated by the incineration process is the sum of the fuel energy requirements, the trash combustion heat generation, and the energy available from sludge material (input). The heat recovered from the incineration process is a function of an input "recovery efficiency" factor.

3.3.2 PYROLYSIS PROCESS

The pyrolysis process is a self-sustaining solid waste disposal system (no start-up or supplementary fuel is required). No waste heat is recovered due to the nature of the process but marketable by-products are created (char,

tar, and combustible gas). The daily generation (lbs) of tar, char, and combustible gas is a function of the temperature and pressure (input) of the pyrolysis process and the total amount of trash to be disposed of. The heating values of the tar, char, and gas are functions of process temperature only. The energy required (input) to sustain the pyrolysis process is obtained from combustion of the required amount of the gas by-product. The remaining portion of combustible gas, along with the tar and char by-products are assumed to be marketable.

As in the incineration process, the daily operating time, size of the unit, and capital cost are functions of the total amount of waste to be disposed of (lbs/hr).

3.3.3 COMBINATION INCINERATION/PYROLYSIS

The combination incineration/pyrolysis process is actually two separate processes with a fixed percentage (input) of the total trash waste being disposed in each process. Waste heat is only recovered from the incineration process. Both incineration and pyrolysis output are printed in this mode.

The total waste heat recovered from the incineration and combination incineration/pyrolysis processes is assumed to be available, in equal hourly increments, for utilization in meeting load demands of the MIUS. The desired hours of utilization are input to this subroutine.

3.4 SUBROUTINE HEAIR

Subroutine HEAIR calculates the heating or cooling loads on a specific building with given internal and external environmental conditions for each hour of a 24 hour day. Input variables define the location, geometry and construction of the building and the internal and external environments. These definitions are provided by the following input variables:

- Latitude, longitude, and time zone of the building location.

- Orientation
- The areas, heat transfer coefficients, azimuth angles, tilt angles and solar absorptance of all external surfaces (windows, walls and roofs).
- Building domestic electric demand profile.
- Building occupancy profile and the metabolic rate profile of the occupants.
- Building ventilation rate profile.
- Inside set-point dry bulb temperature profile.
- Outdoor dry bulb temperature profile.
- Inside set-point enthalpy profile.
- Outdoor air enthalpy profile.
- Clearness of the atmosphere.
- Amount of cloud cover.
- Solar reflectance of the ground surrounding the building.

Four secondary routines are utilized by HEAIR in determining the heating and cooling loads. Subroutines HTLEAK, SUN1, SUN2 and SUN3 determine the heat transfer rate through the walls, roof and windows. SUN1 calculates the sun rise and sun set hours for the day being used for the analysis. SUN2 determines the direct and diffuse solar radiation fluxes for each hour of the day. These fluxes are used by SUN3 to calculate the flux on each surface for each hour of the day. These fluxes are used by HTLEAK in calculating the surface temperature and heat being conducted into the building. The solar flux passing through the window is also determined by HTLEAK from the flux calculations of SUN1, SUN2 and SUN3. The instantaneous heat gain or loss is then converted into a heating or cooling load by HEAIR.

The total heat gain or loss of the building is calculated as the sum of six distinct sources.

- a) The building domestic electricity usage is totally dissipated within the building. Auxiliary electricity usage is not considered to be a heat load source.

$$\begin{aligned}\dot{Q}_{\text{ELEC}} &= \text{domestic usage} \left(\frac{\text{KW-HR}}{\text{HR}} \right) * 3414 \text{ BTU/KW-HR} \\ &= \text{BTU/HR}\end{aligned}$$

- b) Metabolic rate of the occupants (sensible and latent). The sensible and latent heat loads are calculated by empirical equations with metabolic rate per occupant and inside dry bulb temperature as independent variables. When the building is being cooled, both the sensible and latent gain are considered. In the heating mode only sensible is considered.

$$\dot{Q}_{\text{MET}} = (\dot{Q}_{\text{SENS.}} + \dot{Q}_{\text{LAT.}}) * \text{No. of occupants}$$

$$\dot{Q}_{\text{LAT}} = 0.0 \text{ (Heating mode)}$$

- c) Sensible and latent heat loads from ventilation air.
Cooling mode:

$$\dot{Q}_{\text{VENT}} = \dot{\omega} (H_{\text{OUTSIDE}} - H_{\text{INSIDE}})$$

Heating mode:

$$\dot{Q}_{\text{VENT}} = C_p \dot{\omega} (T_{\text{OUTSIDE}} - T_{\text{INSIDE}})$$

Where:

$\dot{\omega}$ = mass flow

H = specific enthalpy

T = dry bulb temperature

C_p = specific heat of air

- d) Conduction heat transfer from the outside environment through the walls, roof and windows.

$$\dot{Q}_{COND} = \dot{Q}_{ROOF_{COND}} + \dot{Q}_{WALLS_{COND}} + \dot{Q}_{WINDOW_{COND}}$$

$$\dot{Q}_{ROOF_{COND}} = UA\Delta T$$

$$\dot{Q}_{WALL_{COND}} = UA\Delta T$$

$$\dot{Q}_{WIND_{COND}} = UA\Delta T$$

U = heat transfer coefficient

A = area

ΔT = temperature differential

- e) Radiation heat transfer through the building window glass to the building interior.

$$\dot{Q}_{RAD} = A_{WINDOW} (DIRSOL + DIFSOL) \text{ where}$$

A = window area

DIRSOL = direct solar radiation flux passing through the glass

DIFSOL = diffuse solar radiation flux passing through the glass

- f) Provision is made for calculation of the heat gain from the use of hot water in the building.

$$\dot{Q}_{HW} = HWF * \dot{Q}_{HWD}$$

\dot{Q}_{HW} = Heat gain from the use of hot water in the building

HWF = Fraction of hot water demand that becomes a heat source

\dot{Q}_{HWD} = Hot water demand

The total building heat gain or loss can be expressed as the sum of these five heat sources.

$$\dot{Q}_{\text{GAIN}} = \dot{Q}_{\text{ELEC}} + \dot{Q}_{\text{MET}} + \dot{Q}_{\text{VENT}} + \dot{Q}_{\text{COND}} + \dot{Q}_{\text{RAD}} + \dot{Q}_{\text{HW}}$$

The above process is repeated for each building type specified by user input. The calculated total heating/cooling demand profiles, the hot water demand profiles (calculated if residential-type building, input if non-residential-type) and the input domestic and auxiliary electrical demand profiles are then summed to comprise the total 24-hour load demand profile.

3.5 SUBROUTINE AIRHT

Subroutine AIRHT calculates, on an hourly basis, the required energy output of the total energy systems (thermal storage, boiler, diesel/generator, and turbine/generator). The energy requirements for the steam power plant prime mover system are calculated internally by subroutine STEAM.

The required energy output is determined by

- Hot water heating loads - calculated or input
- Domestic and auxiliary electric demands - input
- Space heating demands - calculated
- Air conditioning demands - calculated
- Thermal storage system requirements - calculated

For systems using thermal storage, AIRHT calls subroutines AIRTSS (Section 3.24) and HTTSS (Section 3.25). These subroutines perform part of the energy systems analyses.

The domestic and auxiliary electric power demands are met by either a diesel/generator or turbine/generator system, depending on the MIUS operational mode.

During periods requiring heating the hot water heating demands are initially met (partially or fully) by low-grade waste heat energy recovered from the lubrication oil cooling system and water jacket cooling system (if not ebullient cooling) of the diesel/turbine prime mover. If there is low-grade heat left over after meeting the hot water demand, it is used for the space heating demand. If there is enough low grade heat to satisfy both of the above demands, none of the high grade heat recovered from the prime mover exhaust and water jacket (if ebulliently cooled) and the incineration process will be used for these demands. If there is not enough low-grade heat to meet either the hot water or hot water plus space heating demands the high-grade recovered heat will be used. If there is not enough high-grade (plus low-grade) heat to satisfy these demands, the boiler will be fired to meet the necessary remaining demands. During non-heating periods using the absorption air conditioning option, the high-grade heat is used until it is depleted or the total air conditioning demand has been met. If there is not enough high grade heat available a boiler will be fired. If the compression air conditioning option has been chosen the total air conditioning demand is met by use of electric compressors.

The total MIUS electric power load demand is comprised of the domestic and auxiliary demands (program input) and the calculated electric power required to drive the compression-type air conditioning system (when the MIUS is in compression A/C mode).

The air conditioning load demands are met by an air conditioning system that has four modes of operation.

1. All compression
2. All absorption
3. Fixed split - compression/absorption
4. Floating split - compression/absorption

The "Floating Split" system operation is determined by an iterative method that maximizes usage of available waste heat by the absorption system and minimizes electrical consumption by the compression system for each hourly period. Thus, the ratio between compression/absorption air conditioning varies

hourly. The iterative method for the "Floating Ratio" system uses a technique involving up to 25 iterations to ensure that the sum of the absorption A/C load plus the compression A/C load comes within 2 tons of the total air conditioning demand for the particular hour being considered.

Subroutine AIRHT also calculates (when the low grade heat utilization option is selected by the program user) the operating characteristics of a specified cooling tower system, and the amount and utilization of 100°F waste heat recovered from the MIUS air-conditioning system condensers.

The water coolant flow from the MIUS system to the cooling tower is determined by the heat rejection rate of the A/C condenser system, miscellaneous heat rejection requirements, and the cooling capacity of the cooling tower. Coolant water is lost through drift, evaporation, and blowdown processes. This loss is made up with waste water effluent flow. Requirements for the waste heat, before it is sent to the cooling tower, and waste water effluent flow are input to the program. Recovery, utilization, and wastage of the heat and water are summarized in the program output.

The fixed-split system utilizes both compression and absorption in the ratio selected by the user.

3.6 SUBROUTINE GENRAT

Subroutine GENRAT calculates the hourly energy requirements for prime mover/generator units as a function of electrical load demands imposed. The program user may specify the engine/generator set to be used. GENRAT also calculates the hourly rate of waste heat energy that is recovered from prime mover heat exchanger systems. The operating characteristics as a function of percent full rated load are input from subroutine LEAP. Among these operating characteristics are the specific fuel consumption in BTU/KW hr and the recovered waste heat from the engine exhaust, water jacket, and lubricating oil, all in BTU/hr.

The number of specified prime mover/generator units required to meet the electrical load demand is determined by the criteria that a unit can only be loaded to an input maximum (eg. 90%) of its rated full load capacity. Thus, when one unit is loaded to 90% capacity, another unit is brought into operation and the two units operate at 45% load. The number of generators will be a minimum number required to meet the day's maximum auxiliary and domestic electric demand without exceeding a user selected maximum of generator rated output. Each hour's total electric demand (auxiliary, domestic and compression air-conditioning) will be evenly distributed among the generators.

3.7 SUBROUTINE STEAM

Subroutine STEAM calculates the energy requirements and operational characteristics of a MIUS-type steam power plant. Four steam power system configurations are considered and are combined with three solid waste disposal processes to yield twelve unique operating modes. The three solid waste disposal processes have been presented and discussed in subroutine SWDP. Waste heat is available for MIUS utilization from the incinerator process and combination incinerator/pyrolysis process. The four steam power plant configurations are discussed below.

3.7.1 OPTION 1

Figure 3 presents an operational schematic of the "Option 1" steam power plant configuration. The heating demands of the commercial/residential building are met by a low pressure (125 PSIG) boiler system operating at a given efficiency (typically 80%). The cooling and electrical demand are met by a high pressure (850 PSIG) boiler system which supplies steam (850 psig, 900°F) to two turbines, one of which is a straight condensing type that drives for example a 7500 KW generator to meet the electrical demand. The remaining turbine is also a straight condensing type which drives a compression-type air conditioning system to meet cooling demands. The operational efficiency curves of both turbines are considered when calculating required high pressure boiler output. Waste heat recovered from the waste disposal processes is assumed to be available for utilization as part of the required high pressure boiler output.

3.7.2 OPTION 2

Figure 4 presents an operational schematic of the "Option 2" steam power plant configuration. The electrical demands are met by a 7500 KW e.g. generator driven by a condensing turbine (auto-extraction type). The cooling and heating load demands are met by utilizing extracted steam (125 PSIG, 550°F). The cooling load demand is met by an absorption-type air conditioning system and the heating loads are met by a 100% efficient utilization as part of the total high pressure boiler requirements. The high pressure boiler output demand is calculated as a function of the electrical power demand and the steam extraction demand. The high pressure boiler fuel input demand is a function of the output demand and the boiler efficiency (typically 80%).

3.7.3 OPTION 3

Figure 5 presents an operational schematic of the "Option 3" steam power plant configuration. The heating and electrical demand are met by the same equipment and operational mode as described in option 2. The cooling loads are met by a combination compression/absorption air-conditioning system. Extracted steam from turbine #1 is used to drive low pressure turbine #2 (125 PSIG inlet with back pressure of 12 PSIG), which in turn powers a shaft-driven compression type air conditioning system. The exhaust steam (12 PSIG) from turbine #2 is utilized to drive an absorption type air conditioning system. The air conditioning system split is determined by the user. These numbers may be obtained from an energy balance calculation for the operating characteristics of the system.

3.7.4 OPTION 4

Figure 6 presents an operational schematic of the "Option 4" steam power plant configuration. The only differences between options 3 and 4 is that the option 4 turbine #2 is driven directly by the high pressure boiler (850 PSIG, 900°F) and the air conditioning system split has a different ratio.

The required input to perform a steam power plant analysis consists of boiler efficiencies, coefficients of performance (COP) of the air conditioning system, energy required to obtain desired steam conditions at boiler header (Δh , enthalpy, BTU/lb), energy content of steam at turbine extraction points (enthalpy - BTU/lb), and a daily profile (24 values) of heating/cooling demands (BTU/HR). The waste heat recovery profile is calculated by subroutine SWDP and the load demand profiles are calculated by subroutine HEAIR.

The subroutine output consists mainly of the steam power plant energy requirements and the total MIUS energy requirements (energy required for both steam plant and solid waste disposal operation).

MIUS SCHEMATIC FOR STEAM POWER PLANT PRIME MOVER

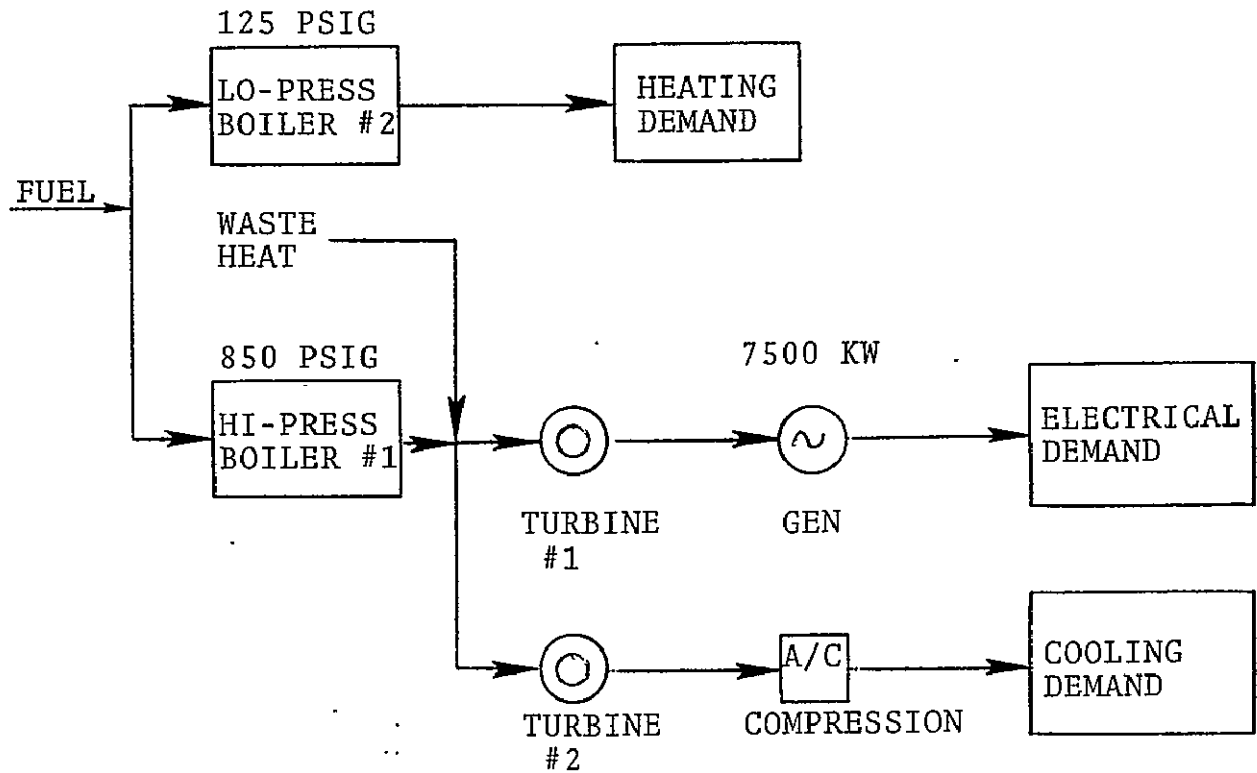


FIGURE 3 STEAM POWER PLANT OPTION 1

MIUS SCHEMATIC FOR STEAM POWER PLANT PRIME MOVER

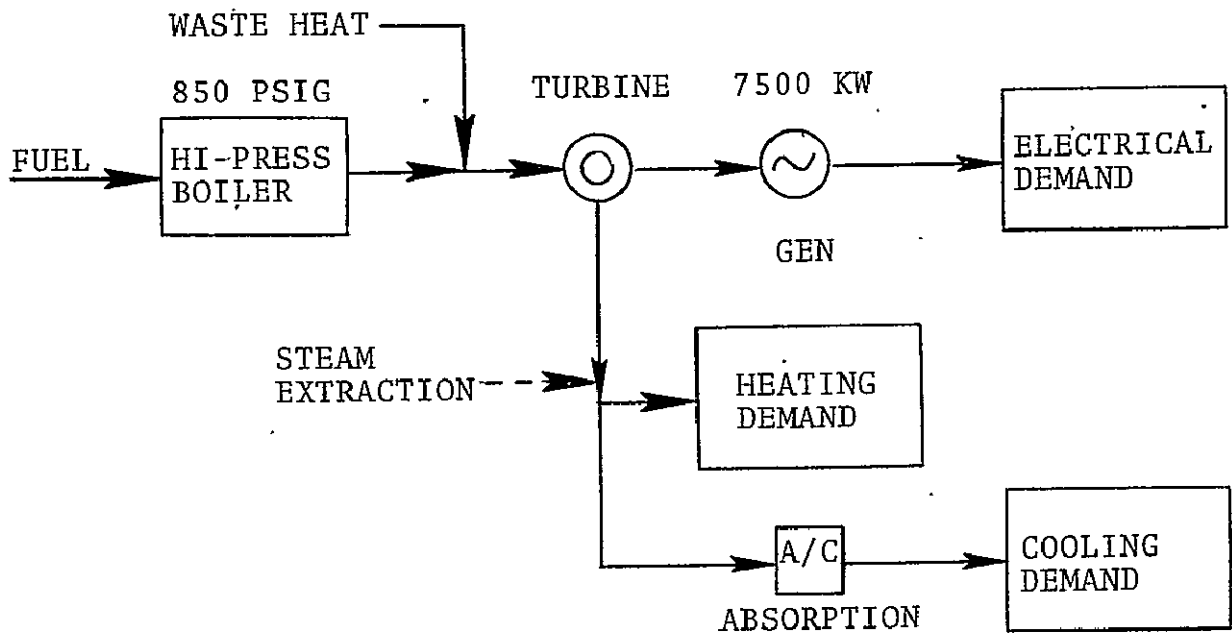


FIGURE 4 STEAM POWER PLANT OPTION 2

MIUS SCHEMATIC FOR STEAM POWER PLANT PRIME MOVER

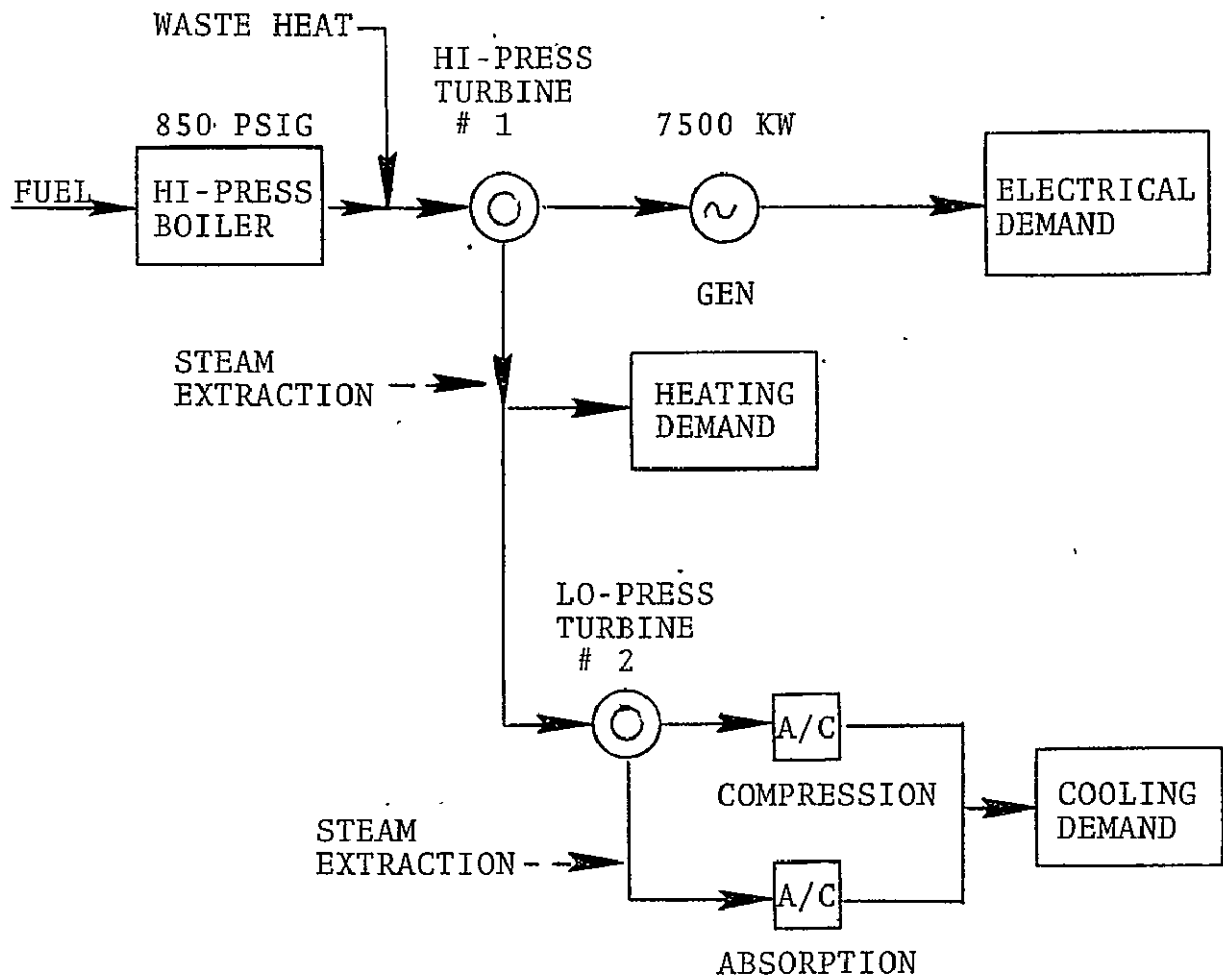


FIGURE 5 STEAM POWER PLANT OPTION 3

MIUS SCHEMATIC FOR STEAM POWER PLANT PRIME MOVER

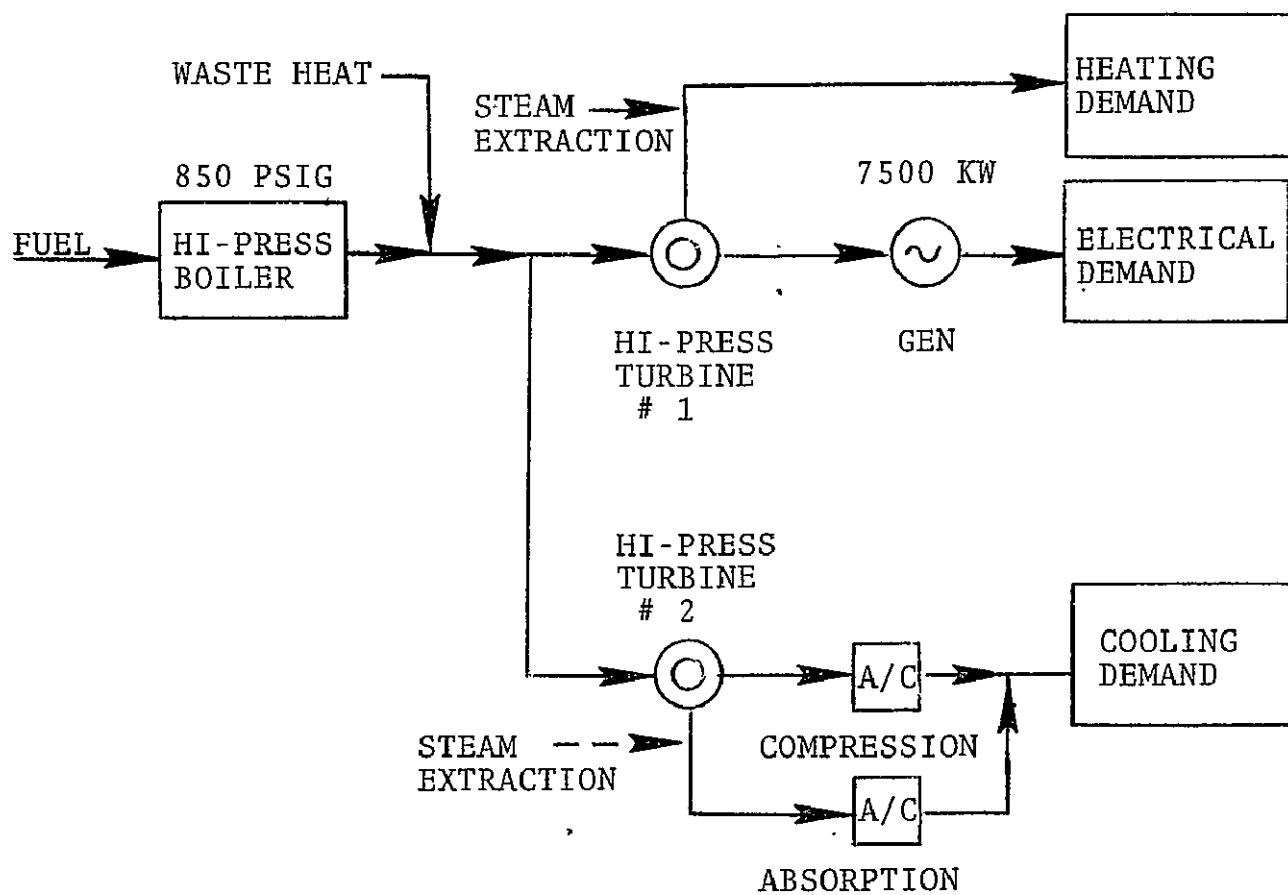


FIGURE 6 STEAM POWER PLANT OPTION 4

3.8 SUBROUTINE CONVEN

Subroutine CONVEN calculates the hourly energy requirements for a conventional (commercial) utility power system to meet the total system load demands as calculated by subroutine AIRHT. The conventional utility system is composed of a boiler system identical to MIUS and a commercial electrical power generating source operating at a specified input efficiency level. Only compression-type air conditioning is utilized with the COP as an input quantity and no waste heat energy is utilized or recovered.

Daily, monthly, and seasonal energy requirements are calculated for comparison with MIUS energy requirements.

3.9 SUBROUTINE INTERP

Subroutine INTERP performs linear interpolation between points of a 13 point two-dimensional curve.

3.10 SUBROUTINE JNTERP

Subroutine JNTERP performs linear interpolation between points of an 8 point two-dimensional curve.

3.11 SUBROUTINE DISCOT

Subroutine DISCOT performs single or double interpolation for continuous or discontinuous functions. For a detailed discussion, refer to NASA/JSC Procedures Manual, Institutional Data Systems Division, Section 5.C.7.1.E.2.1.

3.12 SUBROUTINE UNS (See 3.14)

3.13 SUBROUTINE LAGRAN (See 3.14)

3.14 SUBROUTINE DISSER

Subroutines UNS, LAGRAN, and DISSER are called by subroutine DISCOT for array

dimension calculation and Lagrangian interpolation. Refer to DISCOT documentation for detailed discussion.

3.15 SUBROUTINE PRINT

Subroutine PRINT is the output print routine for subroutine HEAIR which calculates environment, domestic, and auxiliary imposed loads on the MIUS.

3.16 SUBROUTINE OUT

Subroutine OUT is the output print routine for subroutine SWDP which calculates the operational parameters of the three system modes of solid waste disposal.

3.17 SUBROUTINE LIST

Subroutine LIST is the output print routine for subroutine AIRHT which calculates MIUS energy requirements.

3.18 SUBROUTINE WATRP

Subroutine WATRP is a water requirements subroutine in the ESOP2 Program, which predicts the kitchen, laundry, bath and toilet water profiles in a typical residential-type building (i.e., single family residence, town house, garden-level apartment, or high-rise apartment). The subroutine determines the: (1) kitchen hot and cold water profiles, subdivided into those for the sink and dishwasher (rinse and wash water); (2) laundry hot and cold water profiles (rinse and wash water for the washing machine); (3) both hot and cold water profiles (sink and bathtub); and (4) toilet cold water profiles. Details of the calculations may be found in Ref. 4.

Input consists of a residence-type flag and the number of occupants per type of building. The hourly, cumulative hourly, and daily requirements for the kitchen laundry, bath, toilet and total of the previous four are printed out. Also printed out is the percent of hot water to the kitchen, laundry, and bath;

cold water to the kitchen, laundry, bath, and toilet; and total percent of hot and cold water. If a non-residential type building (e.g., office building, regional mall, school, etc.) is being considered, subroutine WATPR is not used and the total heat for hot water, together with the hourly fractional variation, is input.

3.19 SUBROUTINE SUN1

Subroutine SUN1 predicts the sun rise and sun set hours for the day being used for the analysis (see Ref. 5 and 6).

3.20 SUBROUTINE SUN2

Subroutine SUN2 calculates the direct and diffuse solar radiation fluxes for each hour of the day (see Ref. 5 and 6).

3.21 SUBROUTINE SUN3

Subroutine SUN3 computes the flux on each building surface for each hour of the day (see Ref. 5 and 6).

3.22 SUBROUTINE HTLEAK

Subroutine HTLEAK predicts the surface temperature and the heat being conducted into the building. It also predicts the solar heat flux passing through the window from the flux calculations of SUN1, SUN2 and SUN3 (see Ref. 5 and 6).

3.23 SUBROUTINE AIRTSS

Subroutine AIRTSS performs the air conditioning, prime mover and thermal storage analyses during the hours when air conditioning is required, if the MIUS has a thermal storage system. Total electric demand is determined and GENRAT is called to obtain the engine performance and to calculate recovered heat. The absorption and compression air conditioning performance is analyzed and the amount of cooling going into or out of cooling thermal storage is determined. A detailed discussion of the AIRTSS logic is presented in Ref. 7.

3.24 SUBROUTINE HTTSS

Subroutine HTTSS performs the thermal storage analyses when thermal storage is being used during the hours when the system is in a heating mode. The amount of energy going into or out of thermal storage is determined and the amount remaining in thermal storage is calculated. A detailed discussion of the HTTSS logic is presented in Reference 7.

3.25 SUBROUTINE WWPROG

Subroutine WWPROG performs the waste water treatment system analysis. The system water flow (equal to the potable water usage) passes through eleven treatment processes. The change in quality of the water as it passes through each process is determined. The amount of sludge recovered from the treatment is calculated and the sludge is transferred to the Waste-Disposal System for incineration for residential type of buildings.

The waste water treatment processes are logically independent in the sense that the order in which they are used and the number of times any one treatment is used is dependent only on the user's input. However, there may be practical limitations on the order in which the processes should be used. These limitations are explained fully in descriptions of the processes to which they apply in Reference 8. Both generic processes and specific manufacturer's systems are considered in the analysis.

Subroutine WWPROG determines which processes are to be used the order in which they are to occur, the total head pressure involved, and the time at which all treatments have been processed. If there is any selection of equipment involved, the individual treatment subroutines print out the selections made. If all the equipment described within a subroutine is inappropriate because of input values, this information is printed out, but the program does not abort. It processes all remaining requests assuming no changes have been made in any of the waste water parameters because of the missing process or processes. The power requirements for each process are computed and a running total is calculated in the program.

A short description of the subroutine for each of the treatment processes, component selection and output is given in the next sections. Each of the treatment subroutines computes the detention time and the change in water and sludge quality for that particular process.

3.26 SUBROUTINE COMPON

Subroutine COMPON is a component selection subroutine which calls the appropriate treatment subroutine.

3.27 SUBROUTINE RAWTR1

Subroutine RAWTR1 is the subroutine, which performs an analysis of the raw water pumping treatment process. The subroutine selects the optimum pump from a total of 25 pumps whose characteristics are built into the model.

3.28 SUBROUTINE PRTRT1

Subroutine PRTRT1 is the subroutine which performs an analysis of the primary treatment process. The subroutine selects a clarifier tank between six possible types. The amount of concrete for the chosen tank is computed and the horsepower of the required motor is predicted.

3.29 SUBROUTINE BIOLX1

Subroutine BIOLX1 is the subroutine which performs an analysis of the biological flow oxidation process. It is assumed that each bio disk is 6.5 in. in diameter with two sides effective in the process and that there are 17 such disks per running foot of unit. The minimum size is predicted, based on the units being able to handle either: (1) an input loading factor (gpd/ft^2) or (2) an input detention time (hrs).

3.30 SUBROUTINE CHMAD1

Subroutine CHMAD1 is the subroutine which performs an analysis of the chemical addition/mixing process. The subroutine calculates the sizes of the units required, the number of each size, the required horsepower, dimensions of tank, amount of alum required, and amount of water to be added to the influent.

3.31 SUBROUTINE FLOCL1

Subroutine FLOCL1 is the subroutine, which performs an analysis of the flocculation treatment process. This subroutine involves only the sizing of a single tank for each unit, assuming a minimum detention time of 20 minutes and a 1:1 ratio of height to diameter.

3.32 SUBROUTINE CHMCL1

Subroutine CHMCL1 is the subroutine which performs an analysis of the chemical clarification treatment process. The subroutine calculates the dynamic head requirement, sizing of the tank, and total amount of alum added.

3.33 SUBROUTINE FLOST1

Subroutine FLOST1 is the subroutine which performs an analysis of the flow stabilization treatment process. These calculations are similar to those of the flocculation process except that the minimum detention time is 1.75 hours.

3.34 SUBROUTINE CRBAD1

Subroutine CRBAD1 is the subroutine, which performs an analysis of the carbon adsorption treatment process. This process assumes a minimum of two and a maximum of eight carbon columns, which must be sized for each unit. It is assumed that a back flush equal to .75% of the 24 hour flow is subtracted from the effluent.

3.35 SUBROUTINE FILTR1

Subroutine FILTR1 is the subroutine which performs an analysis of the filtration treatment process. For this process, it is assumed that a minimum of two and a maximum of ten filters must be sized for each unit. A backwash of 1.8% of the total influent is subtracted from the effluent.

3.36 SUBROUTINE AERFL1

Subroutine AERFL1 is the subroutine which performs an analysis of the aerated flow equalization treatment process. The total head and pump requirements for this process are computed in the subroutine.

3.37 SUBROUTINE NITRF1

Subroutine NITRF1 is the subroutine, which performs an analysis of the nitrification treatment process. The subroutine predicts the total head and pump requirements for this process.

3.38 SUBROUTINE OUTPUT

Subroutine OUTPUT prints out the results of the sequential treatment of the waste water when all of the processes have been called.

3.39 SUBROUTINE SESOP

Subroutine SESOP is the executive routine for the solar energy heating and cooling analysis. It uses the input which is read in the main subroutine (LEAP) and calls the appropriate subroutines for the analysis to be performed.

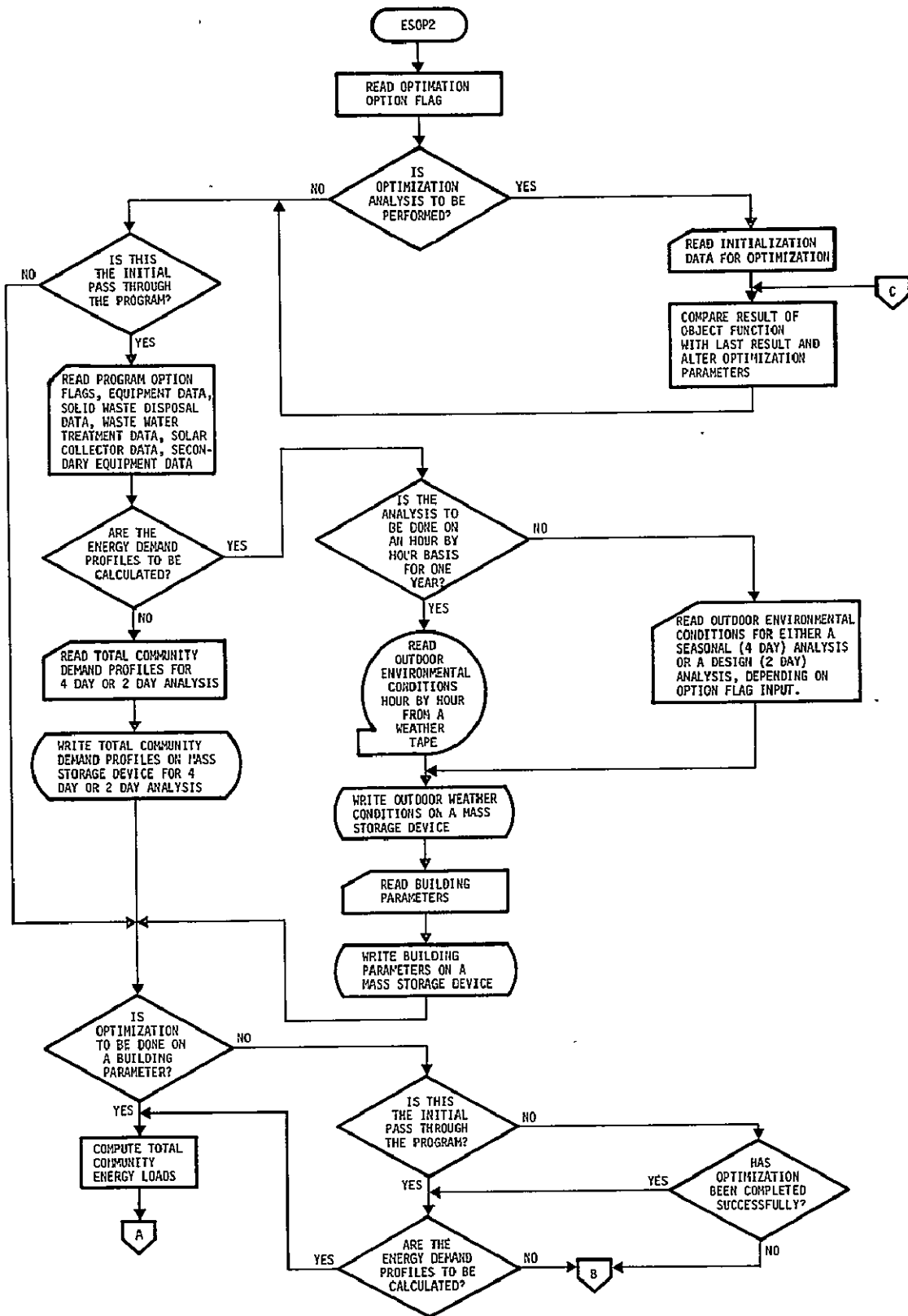
3.40 SUBROUTINE SOLENG

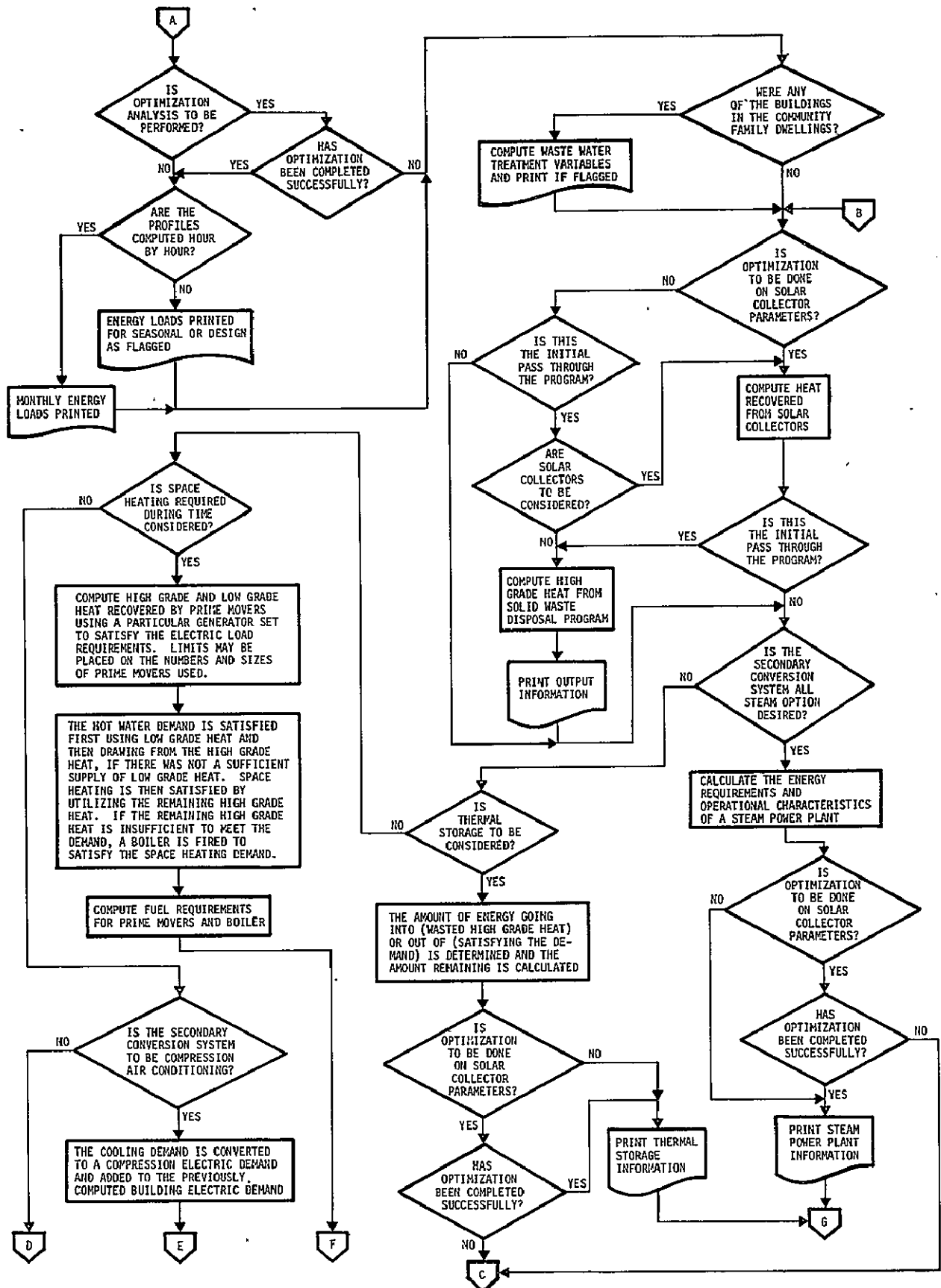
Subroutine SOLENG performs the analysis of the flat plate non-tracking solar collectors and calculates the energy collected by the solar collectors. Subroutines SUN1, SUN2, and SUN3 are called by subroutine SOLENG and are used to calculate the direct and diffuse solar flux on the collectors. A thermal balance on each of the collector surfaces is performed by SOLENG and the collector surface temperature is calculated. The heat transferred from the surface to the water is calculated for up to five collector surfaces. The energy generated is then used in satisfying system

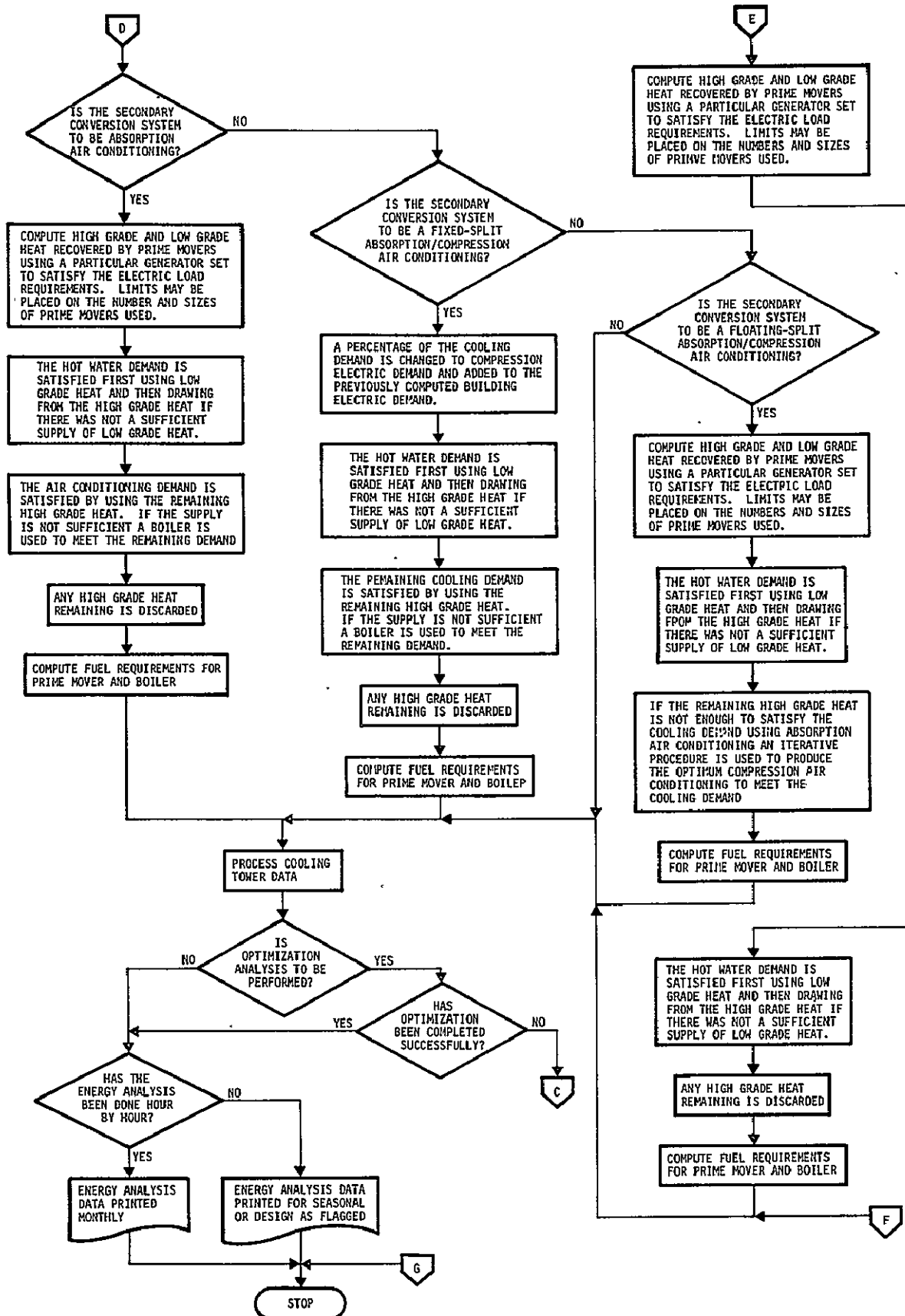
3.41 SUBROUTINE SEARCH

Subroutine SEARCH (Reference 9) is the optimization driver. SEARCH locates a local minimum of a function of up to 20 variables. Each variable is subject to an upper and lower bound. No gradients are required. The author of SEARCH is G. W. Westley at the Computing Technology Center, Union Carbide Corporation, Nuclear Division, Oak Ridge, Tennessee.

4. PROGRAM FLOW CHART







5. CONCLUSION

This document has presented an engineering description of the Energy Systems Optimization Program 2 (ESOP2), as used for MIUS, total energy systems, or conventional utility system application. A general description of the method of analysis was given, with a discussion of the energy systems concept, modeling, and analysis techniques. The details of the three analysis techniques were presented, and a description of each of the subroutines in the program was given. A program flow chart was presented. In summary, it is felt that this program is adequate to meet user needs in determining load and energy analyses for most types of utility or energy system desired.

For information on the use of the program the reader is referred to Volume II. Volume III contains a complete program listing and Volume IV describes the operation and use of the economic data base and financial analysis capabilities.

6. REFERENCES

1. Leighton, G. S., "Modular Integrated Utility System Program", ASHRAE Journal, December 1973.
2. "MIUS - Utilities Breakthrough", Building Systems Design, Dec.-Jan. 1975, pp. 6-11.
3. Rothenberg, J. H., "The Modular Integrated Utility Systems (MIUS) Program", Paper presented at 11th Intersociety Energy Conversion Engineering Conference, September 12-17, 1976.
4. Rochelle, W. C. and Ferden, S. L., "Water Requirements Subroutine for ESOP", Memorandum transmitted to A. E. Brandli (NASA/JSC-USPO), Lockheed Electronics Co., October 1973.
5. Lockmanhekiu, M., "Computer Program for Analysis of Energy Utilization in Postal Facilities", General American Transportation Corporation, Project No. 67138, Construction Research Division, Niles, Ill. 1969.
6. Stallings, R. D., "Correlation of USPS Program and the ESOP Heating/Cooling Load Calculations", TM 4004, Lockheed Electronics Co., Jan. 1974.
7. Ferden, S. L. and Stallings, R. D., "Incorporation of a Thermal Storage System (TSS) into the ESOP", TM 4012, Lockheed Electronics Co., Feb. 1974.
8. Osborne, E. C., "Nine Process Waste Water Treatment Program", TM 4034, Lockheed Electronics Co., May 1974.
9. Westley, G. W., and Watts, J. A., eds: SEARCH, the Computing Technology Center Numerical Analysis Library, Rept. CTC-39, Union Carbide Corp. Nuclear Div., Oak Ridge, Tenn., October 5, 1979, pp. 260-268.